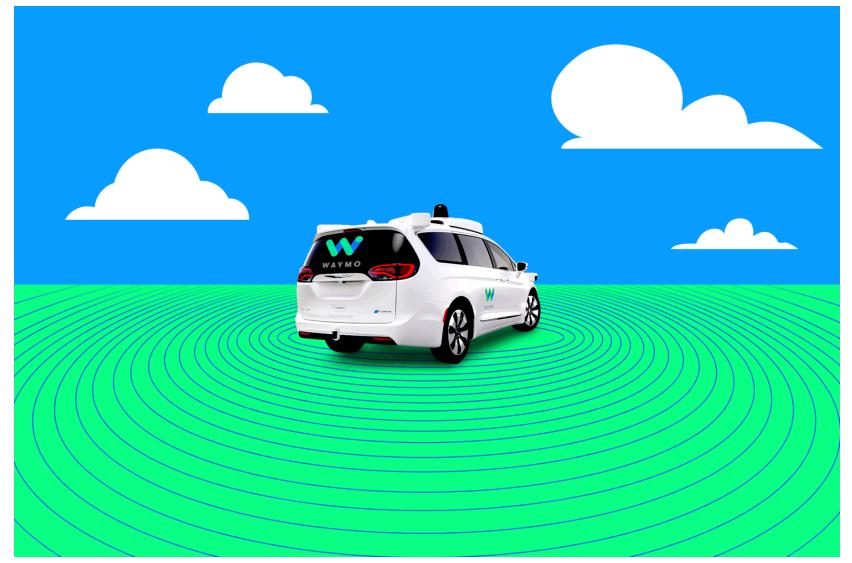
#### AN INTRODUCTION TO AUTONOMOUS VEHICLES



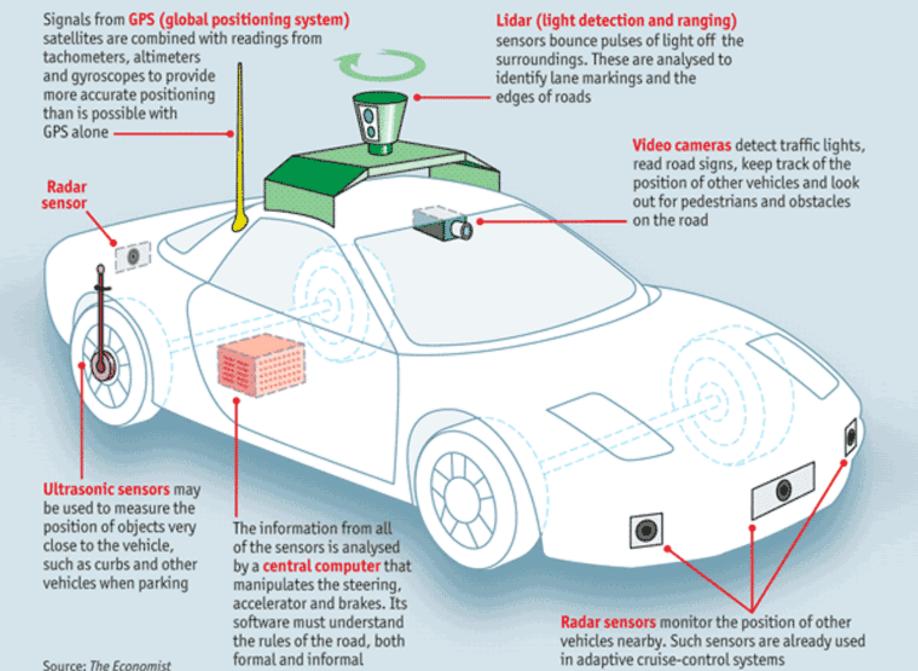
COMPILED BY HOWIE BAUM

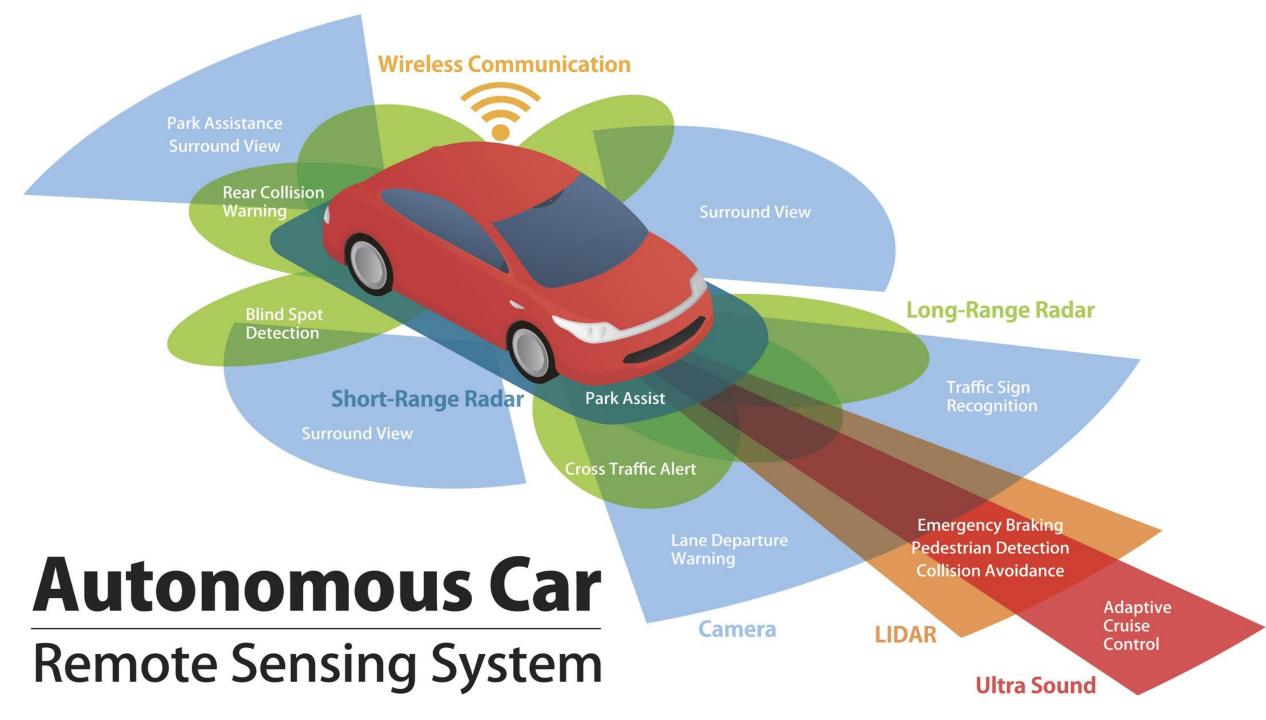
## Autonomous Vehicles Defined

- A vehicle that get from one point to another point, without human interaction.
- To achieve this, they have to use a number of well placed sensors that detect and continuously observe the location and movement of other vehicles, people, and traffic lights, etc.



#### **HOW A SELF-DRIVING CAR WORKS**





- AV (Autonomous Vehicle) TECHNOLOGIES VS. MANUAL OPERATIONS
- Human perception and reaction time: 1.5 Sec.
- AV reaction perception time: 0.1 Sec. using forward, rearward and side sensors
- This capability can reduce the "safe spacing" between vehicles by 50%.

#### AV Technology Expected Impacts on the Transportation System

- AV Technology Projected Impacts may include:
- Increases in highway capacity by  $\sim 100\%$
- Increases in expressway travel speeds by >20%
- Significant reductions in accidents and injuries
- Measurable reductions in future capital improvement needs and being able to allow for higher levels of travel demand

## Drawbacks

- Although there are people who want the technology in their cars, it can cost:
  - \$2,000 on average for safety-related tech (not automation)
  - \$10,000 for the "Cruise" autonomous system in the Audi S4s.
- Poor performance in adverse weather conditions
- Who is to blame in case of an accident ?
  - The car manufacturer?
  - The programmer?
  - The driver?

## **Ethical Considerations**

"Human drivers may be forgiven for making an instinctive but nonetheless bad split-second decision, such as swerving into incoming traffic rather than the other way into a field. But programmers and designers of automated cars don't have that luxury, since they do have the time to get it right and therefore bear more responsibility for bad outcomes."

- Patrick Lin, The Atlantic

# The Lidar System

Features:

- Vertical and horizontal setup of the system possible
- Visual image acquisition with a fully integrated NIKON Digital Single Lens Reflex (DSLR) camera.
- 3D mode of the VZ scanner with continuous rotation of the scanning head for highly efficient mobile data acquisition.
- 360 degree static scanning.
- Mainly used by Google Inc. for detecting the surroundings of their test vehicles.



#### The "Cruise" company System



Features:

- Cameras and Radars to map out surroundings(including other vehicles)
- Used mainly for highway scenarios.
- Steering wheel motor mounted to steering column.
- Adaptive speed control.
- Collision avoidance
- ► RP-1 sensors

(The Cruise company sells the Cruise RP-1 sensor system which is essentially a 'package' that needs integration within cars in order to bring in the selfdriving mechanism that Google's Driverless Cars incorporate.)

Will be made in the future for other vehicles.

# Apples and Oranges

Lidar System:

- \$70,000 system
- Can be used in basically anywhere.
- Design is very bulky and heavy
- Fully autonomous

Cruise System:

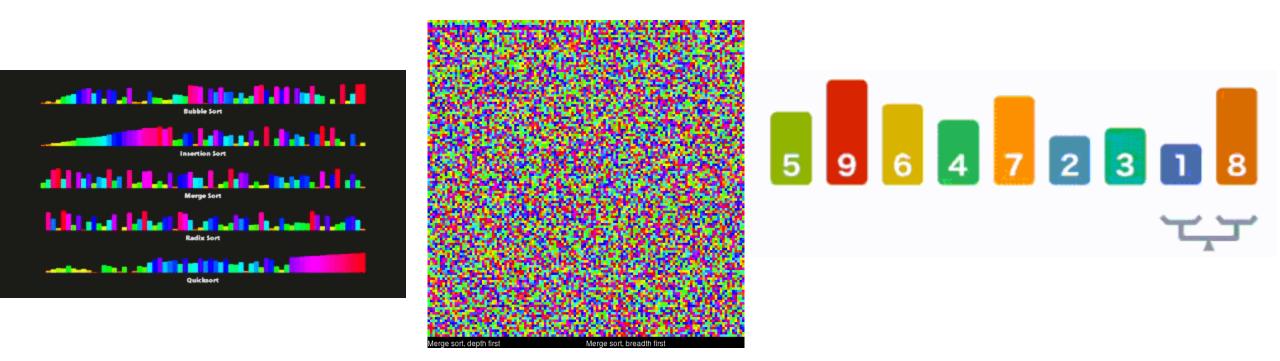
- \$10,000 system (installed)
- Mainly for highway scenarios
- Design is small and lightweight
- Not fully autonomous

Intelligent vehicles cannot achieve human levels of performance until machine vision systems achieve human levels of performance (James Albus, 2009)

#### WHAT DOES THE WORD, ALGORITHM MEAN?

A problem-solving procedure, *algorithm*, is commonly used now for the set of rules a machine (and especially a computer) follows to achieve a particular goal.

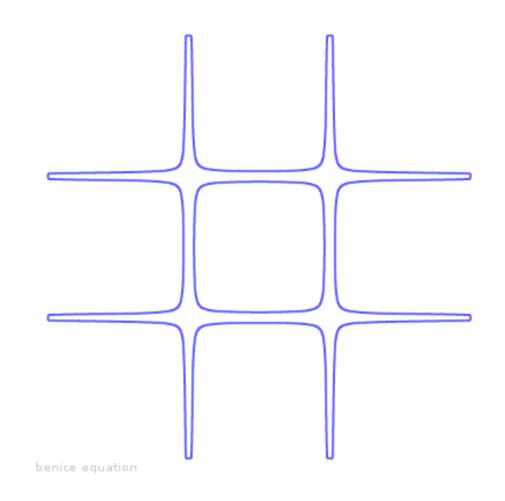
It does not always apply to computer-mediated activity, however. The term may as accurately be used of the steps followed in making a pizza or solving a Rubik's Cube as for computer-powered data analysis.



#### AN ALGORITHM FOR PLAYING TIC TAC TOE

The following algorithm will allow you to always deny your opponent victory or at least end the game in a tie:

- > Win If you have two in a row, you can place a third to get three in a row.
- Block If the opponent has two in a row, you must play the third to block the opponent.
- Fork create an opportunity where you have two threats to win (two nonblocked lines of 2).
- Blocking an opponent's fork If there is a configuration where the opponent can fork, you must block that fork.
- > Center You play the center if open.
- Opposite corner If the opponent is in the corner, you play the opposite corner.
- > Empty corner You play in a corner square.
- > Empty side You play in a middle square on any of the 4 sides.

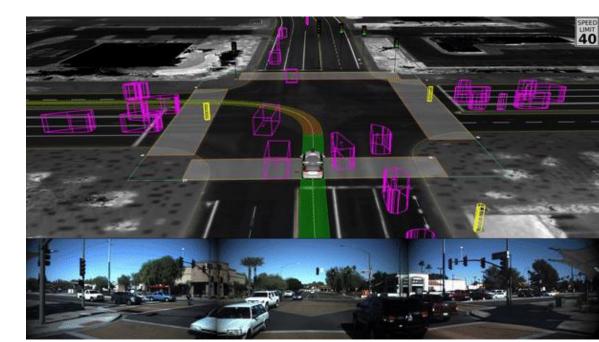


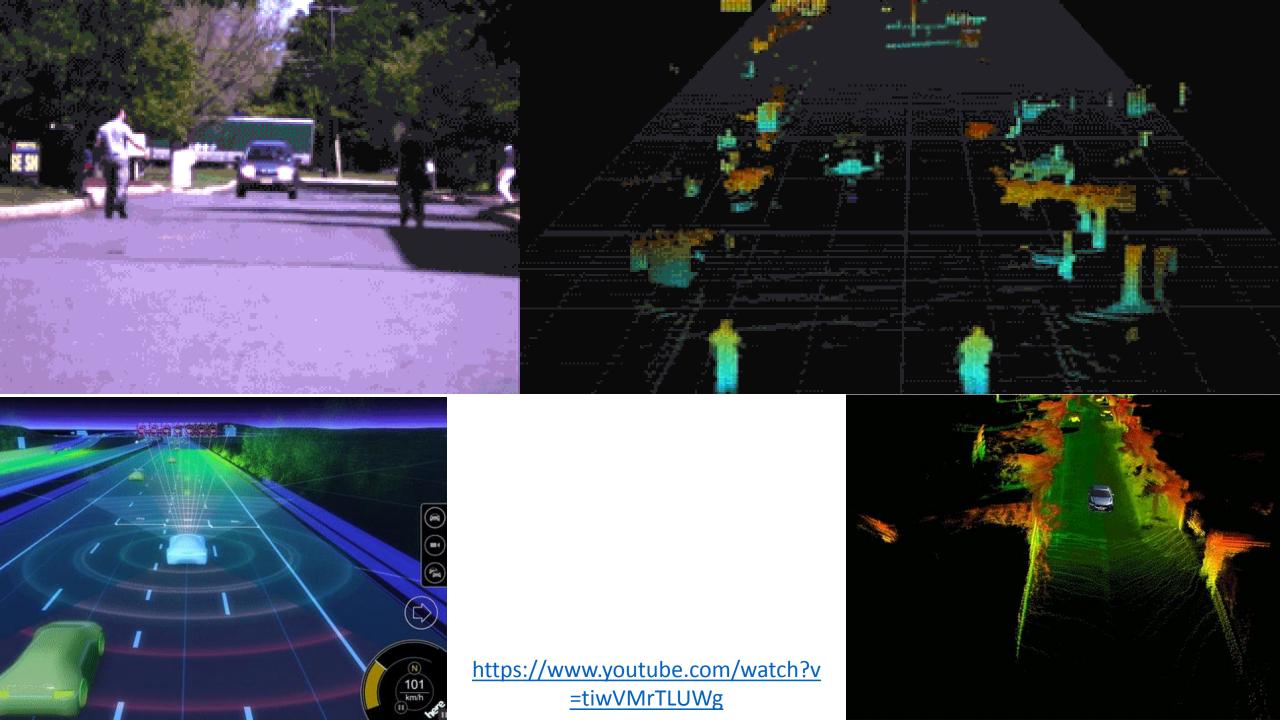
#### **TYPES OF ALGORITHMS NEEDED FOR AUTONOMOUS** The combination of: **VEHICLES**

- 3-D imaging with multiple 1064 nm (nanometer) lasers.
- Edge-Detection algorithm
- Motion-Detection algorithm
- Tracking algorithm

#### LIDAR COMPUTERIZED IMAGES OF THE ROAD







# The Scale of the Problem



#### Safety

35,092 highway deaths in 2015<sup>1</sup>
6.3 million crashes in 2015<sup>1</sup>
A leading cause of death for ages 1-44<sup>2</sup>



#### Mobility<sup>3</sup>

- 6.9 billion hours of travel delay
- \$160 billion of urban congestion





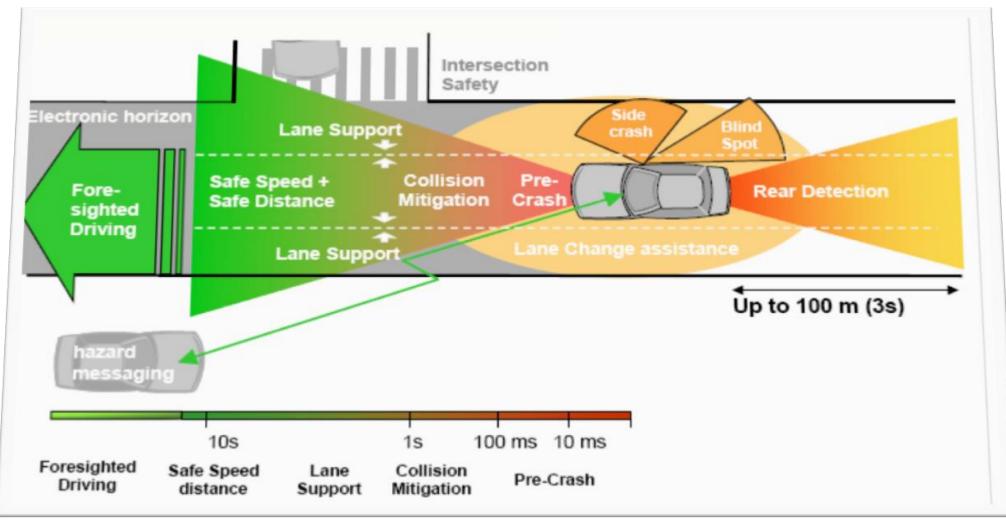
#### Environment<sup>3</sup>

- 3.1 billion gallons of wasted fuel
- 60 billion lbs of additional  $CO_2$



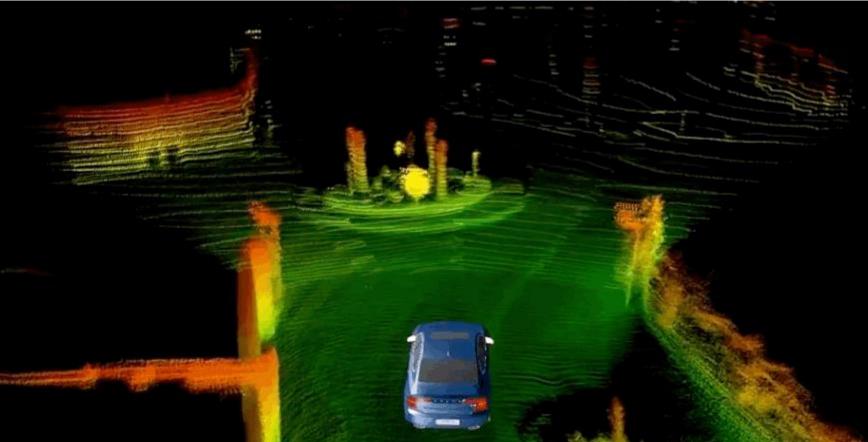
Data Sources: <sup>1</sup>DOT HS 812 318, Traffic Safety Facts, National Highway Traffic Safety Administration (August 2016) <sup>2</sup>10 Leading Causes of Death by Age Group, United States – 2014, Centers for Disease Control and Prevention <sup>3</sup>2015 Urban Mobility Scorecard, Texas A&M **Transportation Institute** and INRIX (August 2015)

# The Opportunity



# What are Autonomous Vehicles?

- AVs combine sensor and map data and based on machine learning (i.e., "experience"), can classify objects in their surroundings and predict how they are likely to behave, in relation to:
  - Other moving vehicles
  - Pedestrians and cyclists
  - Stationary objects (e.g., signs, trees, traffic cones)
- Based on what an AV can "see" and what it predicts nearby objects are likely to do, it can make decisions about speed and steering inputs



#### Example Systems at Each Automation Level

https://www.youtube.com/watch?v=6592pKyQfyE

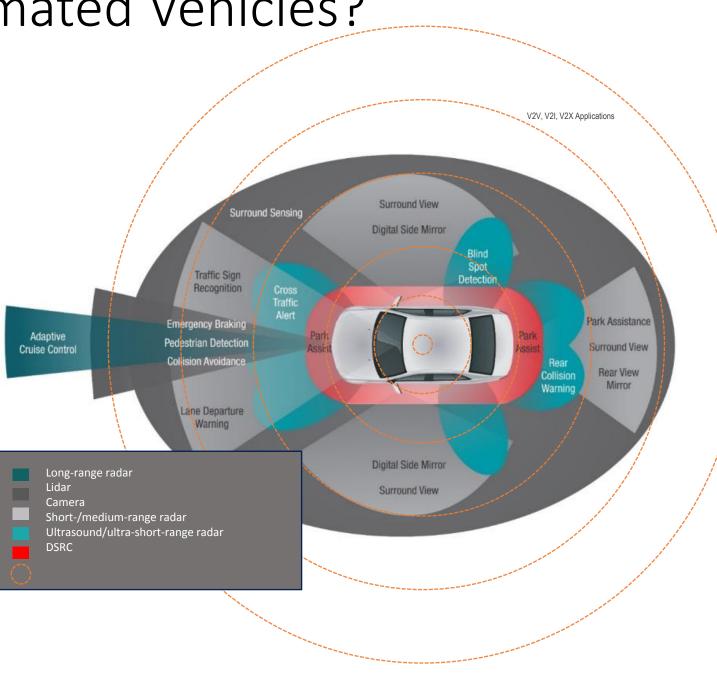
SAE Level	Example Systems	Driver Roles
1	Adaptive Cruise Control OR Lane Keeping Assistance	Must drive <u>other</u> functions and monitor driving environment
2	Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist	Must monitor driving environment (system nags driver to try to ensure it)
3	Traffic Jam Pilot Automated parking Highway Autopilot	May read a book, text, or web surf, but be prepared to intervene when needed
4	Closed campus driverless shuttle Valet parking in garage 'Fully automated' in certain conditions	May sleep, and system can revert to minimum risk condition if needed
5	Automated taxi Car-share repositioning system	No driver needed



\* SAE stands for the Society of Automotive Engineering.

#### What are Automated Vehicles?

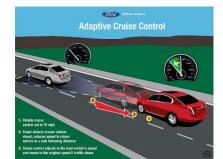
- Automated Vehicles (AVs) fit into the SAE classifications 2 or 3 and are vehicles in which at least one element of vehicle control (e.g., steering, speed control) occurs without direct driver input.
- AVs work by gathering information from a suite of **sensors**.
- These **sensors** may include:
  - Cameras
  - Radar
  - Light detection and ranging (LiDAR)
  - Ultrasonic
  - Infrared light
- AVs may combine sensor data with other inputs, including detailed map data and V2V/V2I inputs. V2V is information from Vehicle to Vehicle. V2I is Vehicle to Infrastructure (surroundings)



## Automated vehicles...on a road near you?

**Here Today** 





Level 1





Level

2



**In Testing** 



Level 3





Someday(?)



Level 4



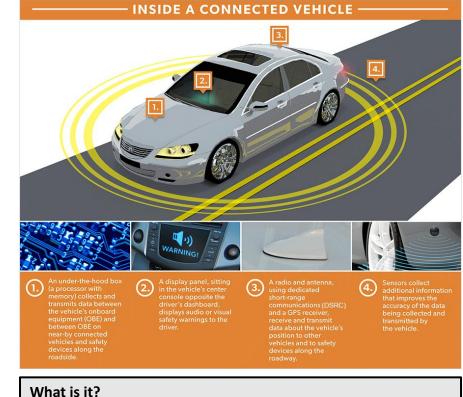
Level 5

# Connectivity Enhances Automated Vehicle Benefits

Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications can enhance the safety and efficiency of AVs by providing greater situational awareness and efficiency.

#### What is a Connected Vehicle?

- 1. An equipped vehicle sends basic safety messages (BSMs), *transmitted 10 times per* seconď
- 2. Other nearby vehicles and roadside equipment receive the messages
- 3. Drivers receive warnings and information to avoid potential crashes and improve mobility



- Dedicated Short Range Communications (Wi-Fi adapted for moving vehicles)
- FCC 5.9 GHz spectrum allocation

### Connected vehicles includes...



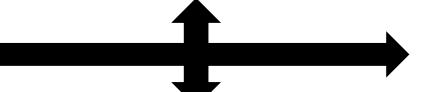


Vehicles and







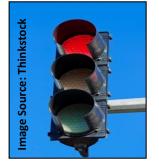




Wireless Devices







cture

Infrastructure Messages Signal Phase and Timing, Fog Ahead Train Coming Drive 35 mph 50 Parking Spaces Available 

#### Vehicle Data

latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height

## Curve Speed Warning

**Curve Speed Warning** Alerts the driver if current speed is too fast for an approaching curve



- Target crashes approaching horizontal curves on segments or interchange ramps that are speed-related
- Alert cars and trucks they are entering a curve at too high a speed to negotiate it safely
- Improve:
  - Reduction in truck rollover and in road departure crashes

## Red Light Violation Warning

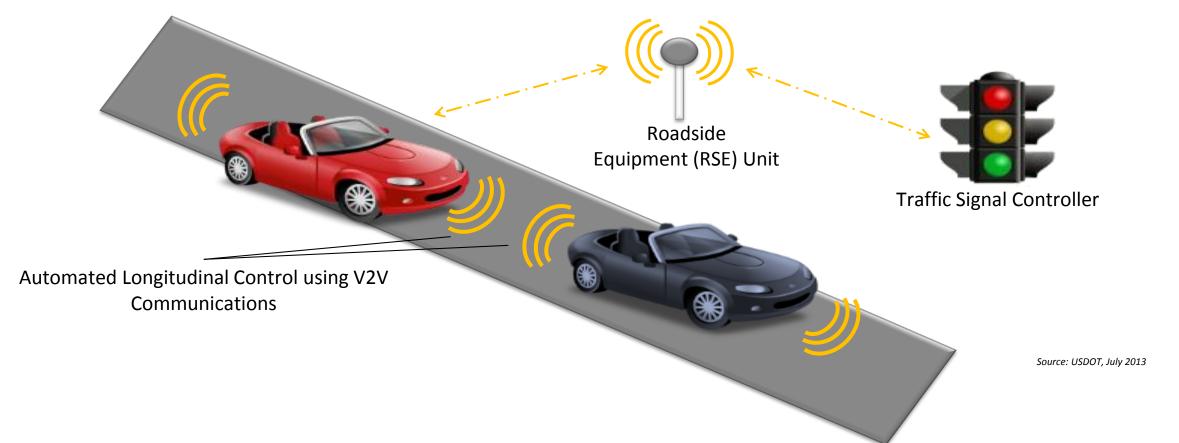
Red Light Violation Warning Issues warning to the driver if he/she is about to run a red light



- Target crashes that result from signal violations
- Wireless exchange of critical safety and operational data
- Reduce the frequency and severity of safety-related incidents
- Improves:
  - Significant reduction in collisions, injuries, and fatalities at intersections
  - Non-recurring congestion resulting from incidents is reduced

## **Eco-Signal Operations Overview**

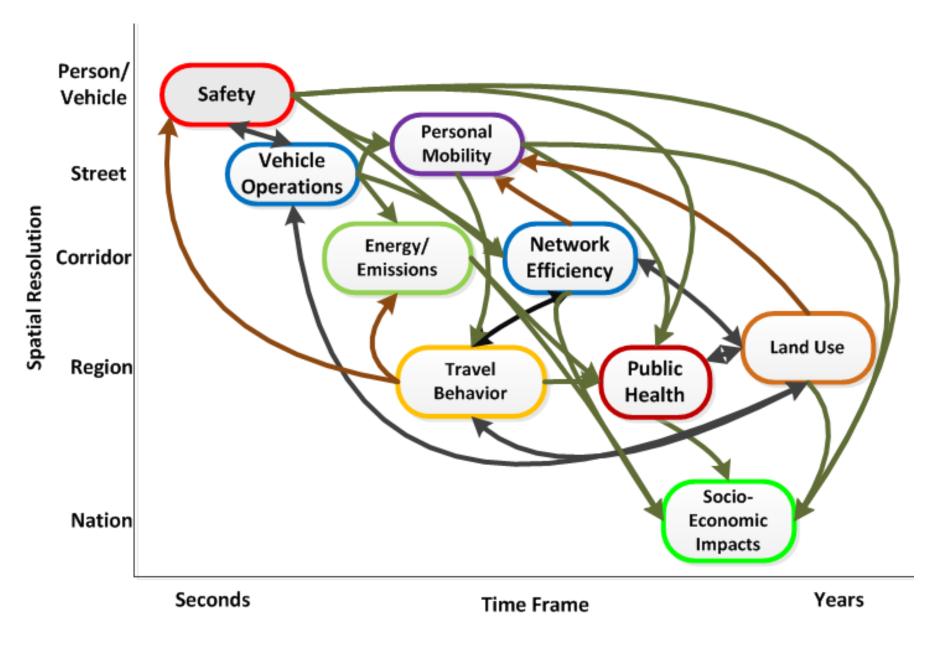
Combined Modeling of Applications: Resulted in a 9.6% reduction in fuel consumption. Use connected vehicle technologies to: reduce idling, number of stops, unnecessary accelerations/decelerations, and improve traffic flow to decrease fuel consumption and emissions



## Mobility and the Environment



#### Impacts of AVs



# Easing Public Apprehensions

- How many more lives per year must be saved for the public to embrace a driverless revolution?
- Manufacturers will need to be upfront with the details of the decision-making systems piloting the vehicles.
- Will there be override capabilities?
- Delayed Feedback Problem: There will be a significant period of time before we've collected enough data to determine the effectiveness of a driverless initiative.

# Terminology – Different words that all mean Autonomous driving:

- Automated (only for classifications 2 and 3)
- Autonomous
- Connected
- Self-Driving
- Driverless
- Automated Driving System (ADS)

#### THIS IS MR. BEAN DRIVING HIS CAR WITH A MOP BUT IT'S NOT AUTONOMOUS, NOR IS THE PHONE BOOTH. IT IS MY FIRST MOBILE PHONE !!





#### **UBER WILL GIVE FREE RIDES FOR ITS SELF-DRIVING CARS DEBUT**

Several tests have been done in the past few months with Uber's self-driving cars and now it is ready to roll out on the streets and get its first passengers. It will offer free rides for customers, in Pittsburgh who will request their autonomous Volvo XC90 sport-utility vehicles from the users' smartphones.



However, the first autonomous Uber trips will have a person in the driver's seat with their fingertips on the wheel as required by law. That person won't be alone as well, as he will have a company representative beside him in the front passenger seat to take notes on a laptop.

Regardless, the ride is free. The public test drive of Uber's XC90 that will happen is just a taste of what lies ahead. Only a few cars will be available for this new system, but Uber has already signed a contract with Volvo, to have 100 vehicles by the end of the year. https://www.youtube.com/watch?v=NodzOaLJENo

## Institutional Grand Challenges

 Adapting public policy and laws for connected and ultimately autonomous vehicles

Assessing and managing system risks

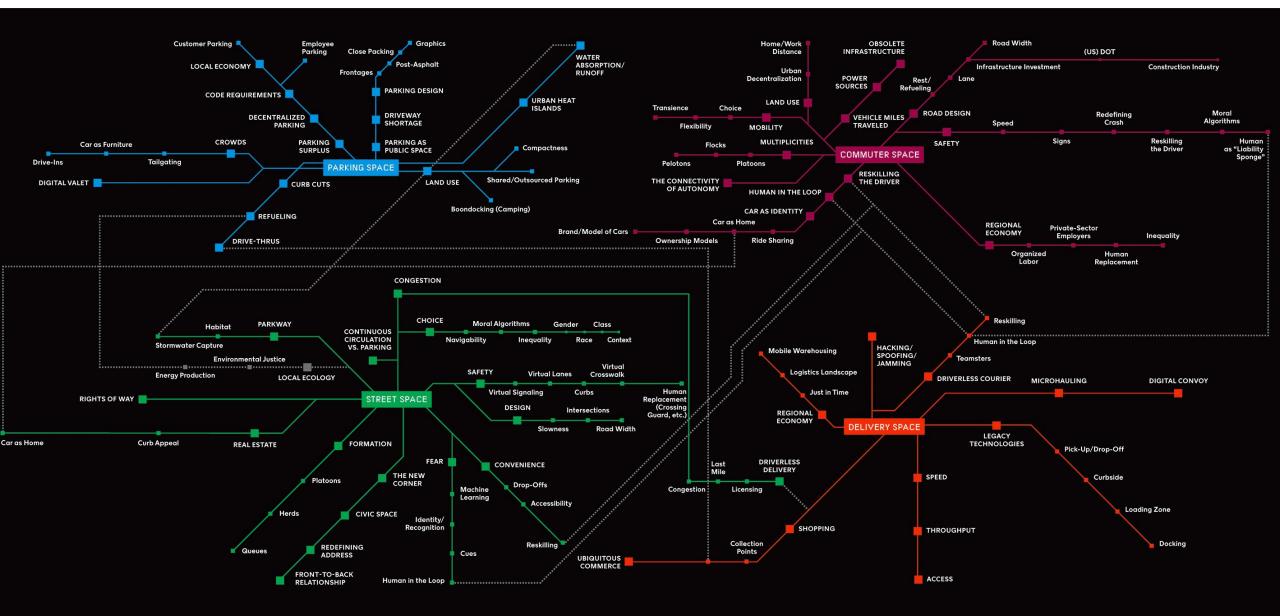


• Establishing new tort liability and insurance systems

• Commercial vehicle operations in the autonomous vehicle era



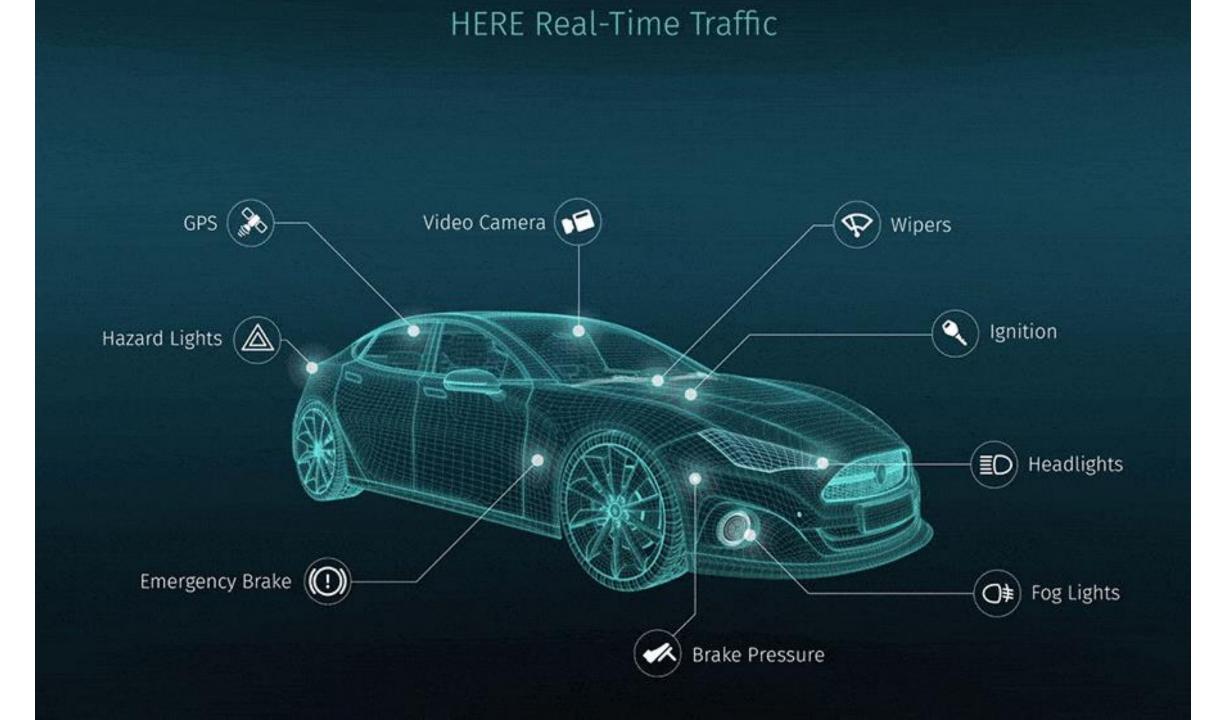
This is a diagram showing all of the factors to consider for Autonomous vehicles in the areas of **Parking Spaces** (blue), **Street space** (green), **Commuter space** (dark red), and **Delivery space** (lighter red)





#### CADILLAC SUPER CRUISE !

https://www.youtube.com/watch?time\_continue=3&v=\_rxW68ADIdI



# SELF DRIVING CARS

1939 The concept is introduced at a World's Fair by GM

**1977** Japan comes up with a fully autonomous car

### 1980s

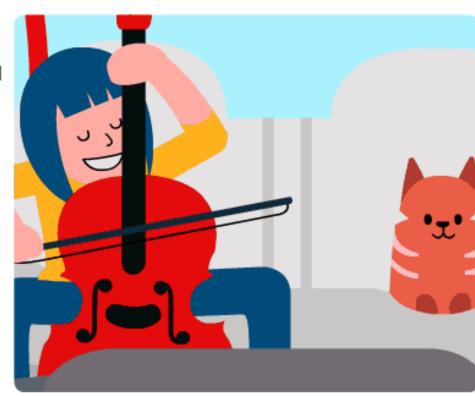
Europe gains a footing in AVs with Navlab, ALV and EUREKA

### 2014

Google releases a prototype of a 100% autonomous car

# 2015

Tesla releases a level 2 -3 AV as a software update



## FUN FACTS

100% autonomous cars expected to be released to the general public by 2021

WIRED anticipates that by 2040, people will no longer need driving licenses!

## TECH

A combination of GPS, Radar, lidar, odometry and computer vision

# 6 Levels of autonomy

Lv O: Can only issue warnings Lv 1 -2: Limited driver assistance Lv 3: Limited autonomy Lv 4: Highly autonomous Lv 5: 100% autonomous





# Traffic Ahead

Many carmakers are developing prototype vehicles that are capable of driving autonomously in certain situations. The technology is likely to hit the road around 2020.

	BMW	Mercedes-Benz	Nissan	0-0	
				Google	General Motors
VEHICLE	5 Series (modified)	S 500 Intelligent Drive Research Vehicle	Leaf EV (modified)	Prius and Lexus (modified)	Cadillac SRX (modified)
KEY TECHNOLOGIES	Video camera tracks lane markings and reads road signs	Stereo camera sees objects ahead in 3-D Additional cameras	Front and side radar Camera	LIDAR on the roof detects objects around the car in 3-D	Several laser sensors Radar
	Radar sensors detect objects ahead	read road signs and detect traffic lights	Front, rear, and side laser scanners	Camera helps detect objects	Differential GPS Cameras
	Side laser acanners Ultrasonic sensors	Short- and long- range radar	Four wide-angle cameras show the driver the car's	Front and side radar	Very accurate map
	Differential GPS	Infrared camera	surroundings	unit tracks position	
	Very accurate map	Ultrasonic sensors		Wheel encoder tracks movement	
				Very accurate map	



#### Autonomous Modes of Transport Can Help Cities Achieve Their Goals

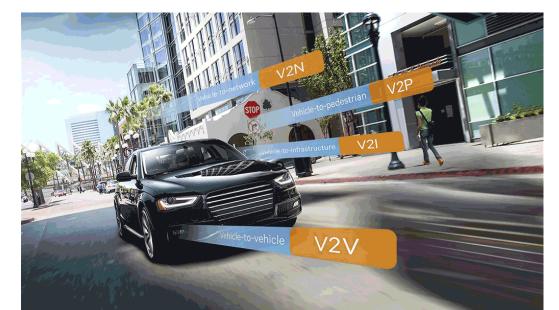


Sources: World Economic Forum; City of Boston; BCG analysis. <sup>1</sup>Based on modeling of a hypothetical city with 5 million inhabitants over a ten-year period. <sup>2</sup>Based on a 24-hour traffic simulation of Boston's downtown core. Self driving cars will be connected through a variety of communications systems now under development that ultimately will become **part of the new 5G Phone Network.** 

Most road transportation today is using wireless communications, both for its operation as well as offering connectivity, entertainment and information services to "passengers".

These vehicles will be using what best will be offered in terms of **4 wireless communications** systems:

- Manufacturers are already experimenting a variety of solutions (under the label V2V Vehicle to Vehicle and V2I Vehicle to Infrastructure) that eventually will merge under the new 5G phone network label.
- > V2P stands for vehicle to Pedestrian and V2N stands for Vehicle to Network.



#### Factors that May Delay the Acceptance and Use of Self-Driving Cars

Article written by Lou Frenzel | Jan 09, 2019

From lack of confidence in safety to job loss, there are some main questions that continue to swirl around, and ultimately hinder, the autonomous vehicle's commercial progress.

A recent Axios survey indicates that only about 66% of Americans said they feel unsafe around AVs. 80% of seniors fear AVs.

An earlier AAA survey identified that 73% of Americans said they're afraid to ride in an AV and 63% said they felt that the road was unsafe with when sharing the road with AVs.

- What if the regulations, insurance, etc. of AVs are so strict that adoption will not be in the volume expected?
- > What if cities limit the use of AVs to specific areas or roads?
- > Will AV taxis really be viable? Will you ride in one?
- Will the benefits of AV trucks, including 18-wheelers, actually lower transportation costs and improve safety?
- > Are AV buses viable? Would you let your kids or Grandkids ride in an AV school bus?
- > What is the economic impact on all those millions of truck, taxi, and bus drivers who lose their jobs to AVs?
- > Will the expected initial real-world AV price of over \$100,000 seriously limit the sales of AVs?

### 44 vehicle manufacturers worldwide are now actively developing self-driving cars



#### POD ZERO AUTONOMOUS CARS WILL MAKE PUBLIC TRANSPORTATION OUT OF ADVERTISEMENTS

"Pod Zero represents the next generation of pod and features different drivetrain, steering systems, and a new striking interior that is dominated by video screens that can play adverts, information videos, or just become neutral to showcase the view from the outside," David Keene, CEO of RDM Group, told the <u>Coventry Telegraph</u>.

The new pods come with room for two, four, and eight passengers. RDM Group develops cars for a "Low-Speed Autonomous Transport System (or L-SATS)." While the low maximum speed keeps the pods from being useful on city streets, <u>RDM Group</u> lists airports, theme parks, shopping centers, college campuses, and smart cities as ideal locations.



### NURO & KROGER DEPLOY SELF-DRIVING CARS FOR GROCERY DELIVERIES IN ARIZONA

Self-driving, electric vehicle startup Nuro – founded by two ex-google engineers – not only revealed to the world their R1 prototype in january 2018 but also announced a partnership with Kroger, the largest supermarket chain in the US.

The idea was simple: the driverless pods, which feature two storage compartments that, obviously, open automatically, would transport local goods such as groceries, dry cleaning and even pizza orders. starting on august 16th 2018, the collaboration is piloting autonomous deliveries of groceries

in Scottsdale, Arizona.



https://www.youtube.com/watch?v=XKXbacNQGI8

WAYMO - It's 2018, and <u>Waymo</u> is doing it live. Two months after the Alphabet (the parent company of Google) self-driving car spinoff announced it would start running a truly driver-free service in Phoenix this year (as in, <u>cars romping about with no one at the wheel</u>), the company now unveils how it will do it: with the help of thousands more Chrysler Pacifica hybrids.

The vehicles, built by Fiat Chrysler in Canada, will eventually make their way to the cities where Waymo is currently testing driverless tech. Waymo already uses 600 of the minivans to test its

driverless software.



https://www.youtube.com/watch?v=B8R148hFxPw

**AUTONOMOUS TRUCKS !!** IF YOU LIVE in Southern California and you've ordered one of those fancy new smart refrigerators in the past few weeks, it may have hitched a ride to you on a robo-truck.

Since early October, autonomous trucks built and operated by the startup **Embark** have been hauling Frigidaire refrigerators 650 miles along the I-10 freeway, from a warehouse in El Paso, Texas, to a distribution center in Palm Springs, California. A human driver rides in the cab to monitor the computer chauffeur for now.

"This is the first time someone has demonstrated this end-to-end," **Embark** CEO Alex Rodrigues says. "It showcases the way that we see self-driving playing into the logistics industry."

**Embark** is one of many companies that believe semi-s, not personal cars, are the smartest use of autonomous technology, or at least the best way to get it onto the road ASAP.





Major players like Volvo and Daimler are working on their own robo-truckers.

So is Elon Musk's Tesla.

Waymo (the company formerly known as Google's self-driving car effort) is thinking about putting its tech to use in big rigs.



#### VERA: VOLVO'S AUTONOMOUS ELECTRIC VEHICLE OPTIMIZES DELIVERY

Meet Vera: an autonomous electric vehicle from Volvo that is controlled and monitored from the cloud and provides a safer, cleaner mode of transportation. These vehicles can locate their position within centimeters and analyze what happens with other road users.

Vera doesn't make a whole lot of noise. It is equipped with sensors, radars, and cameras for maximum safety and efficiency. The video explains what this exciting idea is all about.



https://www.youtube.com/watch?time\_continue=116&v=2Gc1zz5bl8I

#### **MERCEDES-BENZ FT2025 IS NEW DAIMLER TRUCKS FLAGSHIP**

-- The vast majority of S-Class-level active safety and automated driving tech is all-new to the long-haul truck segment.

Daimler Trucks is the top-selling medium and heavy truck supplier worldwide, so these ideas will populate everything from future Unimogs to the new Daimler India brand BharatBenz in the coming years.

The active safety is only half the battle: efficiency via aerodynamics is the other half of the coin. The truck and the trailer show revolutionary improvements in aerodynamics. This innovative design is clearly the best the Daimler Trucks and Mercedes-Benz teams could achieve versus the wind.



https://www.youtube.com/watch?v=5u5WXd-kaSs

#### AUTONOMOUS TRUCK PLATOONING OR CONVOYING, USING ELECTRONIC SIGNALS BETWEEN EACH ONE



https://www.youtube.com/watch?v=lpuwG4A56r0

#### **CES (CONSUMER ELECTRONICS SHOW) 2019: JOHN DEERE HIGHLIGHTS TRACTORS' AUTONOMY**

A John Deere combine is more at home among rows of corn than at the giant Consumer Electronics Show in Las Vegas this week, but that didn't stop Deere & Co. from bringing farm equipment to the technology confab.

The company had a booth at CES for the first time. It was dominated as much by the vehicle as it was by the message that technologies like autonomous driving and highly precise GPS data play a vital role in today's farm life.

"Finding qualified skilled labor in rural America is getting harder and harder, and farmers see autonomous driving as a tool that helps them hire less skilled operators to work in the cab," said Deanna Kovar, Deere's director of production and precision for agricultural marketing.

"We're here to help folks understand how technology applies to agriculture"



https://www.youtube.c om/watch?v=mYEHvu Dq2Fs

https://www.youtube.com /watch?v=iYpCEq48Nbw

# THE WORLDS FIRST SELF-DRIVING SEMI-TRUCK WAS LICENSED IN NEVADA IN MAY, 2015.



https://www.youtube.com/watch?v=xBVq\_3DIsUY

Of course, you want to be sure the sensors are working in the big Truck !!





#### **INTERESTING AND THOUGHT PROVOKING PREDICTIONS**

1) Most (the smart) major auto manufacturers have already designated money to start building new plants that only build electric cars.

2) Auto repair shops will go away.

A gasoline engine has 20,000 individual parts. An electrical motor has 20. Electric cars are sold with lifetime guarantees and are only repaired by dealers. It takes only 10 minutes to remove and replace an electric motor.

3) Gas stations will go away.

4) Parking meters will be replaced by meters that dispense electricity. Companies will install electrical recharging stations; in fact, they've already started. You can find them at select Dunkin' Donuts locations.

5) Gasoline/oil companies will go away. Drilling for oil will stop. So say goodbye to OPEC!

6) A baby of today will only see personal cars in museums.

7) UBER is just a software tool, they don't own any cars, and are now the biggest taxi company in the world! Ask any taxi driver if they saw that coming.

8) Autonomous cars: In 2018 the first self-driving cars are already here. In the next 2 years, the entire industry will start to be disrupted.

9) You won't want to own a car anymore as you will call a car with your phone, it will show up at your location and drive you to your destination.

10) You will not need to park it you will only pay for the driven distance and you can be productive while driving.

11) The very young children of today will never get a driver's license and will never own a car.

12) This will change our cities, because we will need 90-95% fewer cars. We can transform former parking spaces into parks

13) 1.2 million people die each year in car accidents worldwide including distracted or drunk driving. We now have one accident every 60,000 miles; with autonomous driving that will drop to 1 accident in 6 million miles. That will save over a million lives worldwide each year.

14) Most traditional car companies will doubtless become bankrupt. Traditional car companies will try the evolutionary approach and just build a better car, while tech companies (Tesla, Apple, Google) will do the revolutionary approach and build a computer on wheels.

15) Right now Volvo won't be making or installing anymore internal combustions engines in their vehicles starting this year with the 2019 models, using all electric or hybrid only, with the intent of phasing out hybrid models.

16) Insurance companies will have massive trouble because, without accidents, the costs will become cheaper. Their car insurance business model will disappear.

17) Real estate will change. Because if you can work while you commute, people will move farther away to live in a more beautiful or affordable neighborhood.

18) Electric cars will become mainstream about 2030. Cities will be less noisy because all new cars will run on electricity. Cities will have much cleaner air as well.

#### WELCOME TO TOMORROW – IT ACTUALLY ARRIVED A FEW YEARS AGO !

### A LOOK INTO THE AUTONOMOUS FUTURE !!



https://www.youtube.com/watch?v=Z7pFnMNFwDc